# Enhanced Head-Up Display for General Aviation

*For the*
*Quarterly Review of the NASA/FAA Joint University Program for Air Transportation Research*

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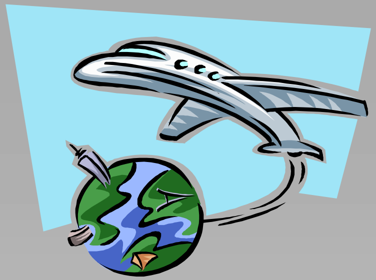
**Avionics Engineering Center**

**Ohio University, Athens**



**Project Sponsor: Joint University Program**



# Introduction

- General Aviation Instrumentation has undergone little change in the past 50 years.
- In 1999, 73% of the fatal accidents were caused by night Instrument Meteorological Conditions (IMC).
- IFR traffic is expected to increase by 2.5 percent per year over the next decade.
- Increase in IFR traffic might lead to a possible increase in GA accidents.

# Overview

- Motivation Behind eHUD
- Pseudo-Attitude Determination
- Current eHUD System Overview
- Flight Test
- Performance Requirement Analysis
- eHUD Architectural Overhaul
- Future Upgrades

# Motivation Behind eHUD

- Provide Visual Cues in IMC.
- Increase Situational Awareness in IMC.
- Reduce pilot training and recurrency requirements for flight in IMC.
- Keep the pilot looking out the window at the same time they are flying the instrument approach.
- Cost effective Head-Up Display.

# Attitude

The Merriam-Webster Dictionary defines *attitude* as the position of an aircraft or spacecraft determined by the relationship between its axes and a reference datum.

**Traditional Attitude:**

- Three GPS Receivers, three Antennas.
- Expensive and Computationally Intensive.

**Pseudo-Attitude (*Velocity Vector Based Attitude*):**

- Observable from a single GPS antenna.
- Cost effective to purchase and install.

# Pseudo-Attitude Determination

(*Velocity Vector Based Attitude Determination*)

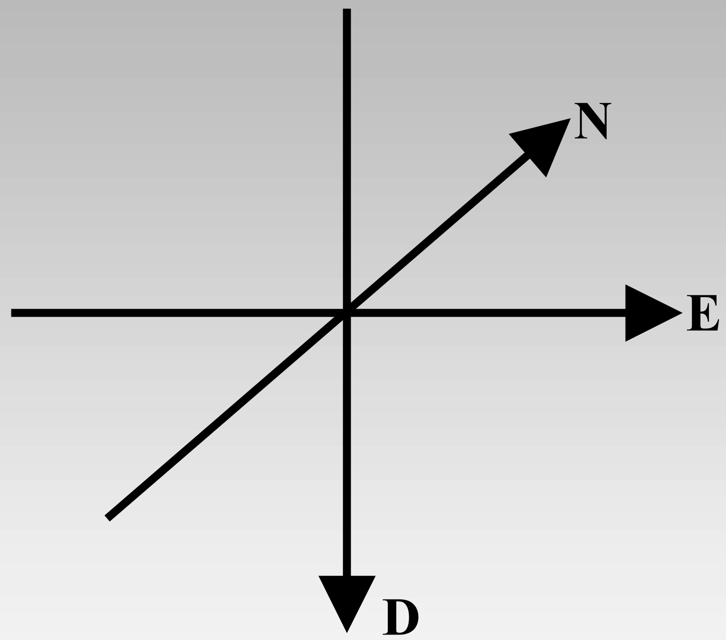
Developed at the Massachusetts Institute of Technology by:

- Dr. Richard P. Kornfeld
- Dr. R. John Hansman
- Dr. John J. Deyst

The information on the following slides, regarding Velocity Based Attitude, was taken from "***The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture***" Report No. ICAT-99-5, June 1999.

# Reference Frame

(*North, East and the Local Vertical Down.*)



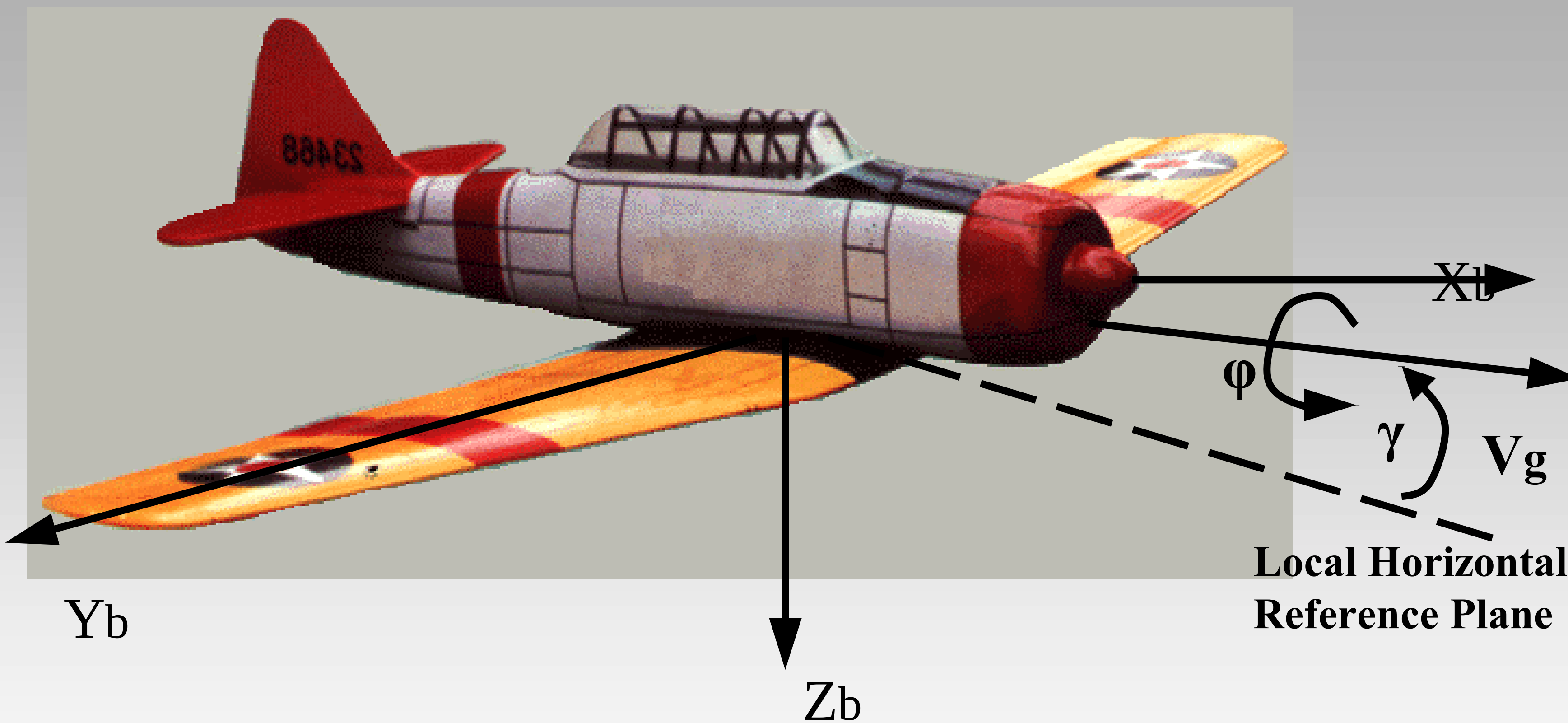

$$\mathbf{N} \times \mathbf{E} = \mathbf{D}$$

***Velocity Vector***

$$V_g = (V_{gN}, V_{gE}, V_{gD})$$

***F*NED:** Earth-Fixed locally level coordinate system.

# Pseudo-Attitude

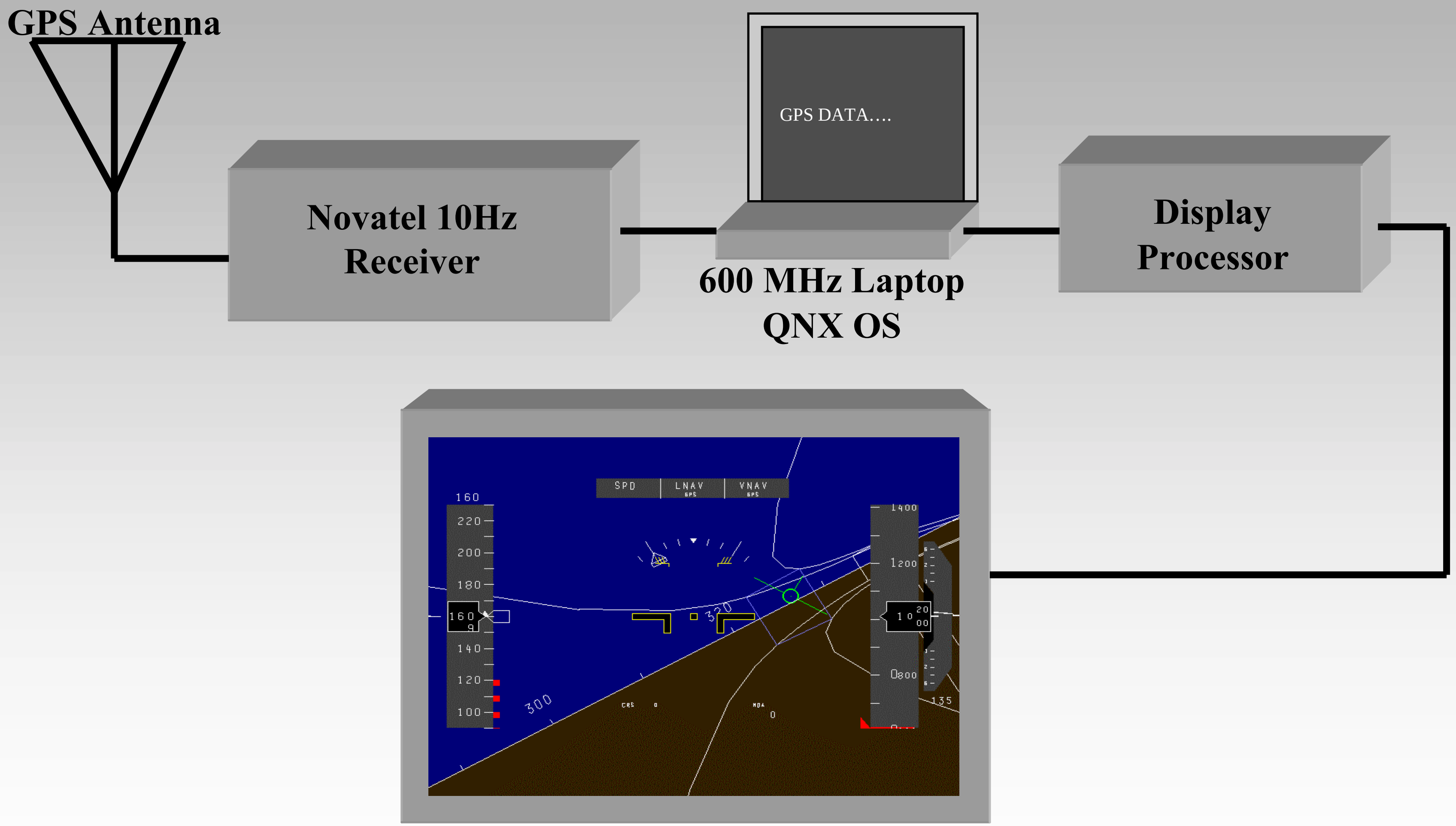



Flight Path Angle : $\gamma$

Pseudo-Roll Angle : $\varphi$

***F*<u>B:</u>** Body-fixed orthogonal axes set which has its origin at the aircraft center of gravity.

# Current eHUD Configuration



# GPS Receiver

**Novatel 10Hz Receiver**

Novatel GPS Receiver

- 10 Hz Velocity Data
- 5 Hz Position Data
- RS-232 serial port

GPS Receiver provides position and velocity information to the real-time processor for ***Pseudo-Attitude Determination.***

# Position and Velocity Strings

$**POSA**,637,511251.00,51.11161847,-114.03922149,1072.436,…

$**SPHA**,640,511251.00,0.438,325.034,2.141,…

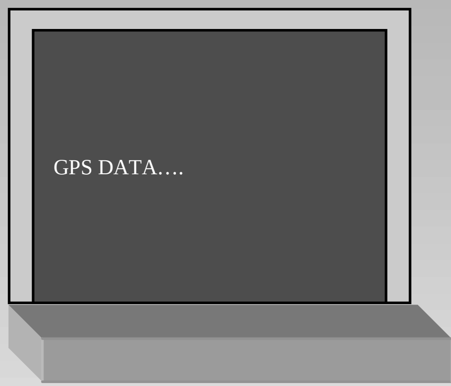
**Position (POSA)**

- GPS Sec into the Week.
- Latitude
- Longitude
- Height

**Velocity (SPHA)**

- GPS Sec into the Week.
- Horizontal Speed (m/s)
- Ground Track (degrees)
- Vertical Speed (m/s)

# Real Time Processor




Gateway 600 MHz Laptop.

- QNX Real-Time OS
- PCMCIA Card

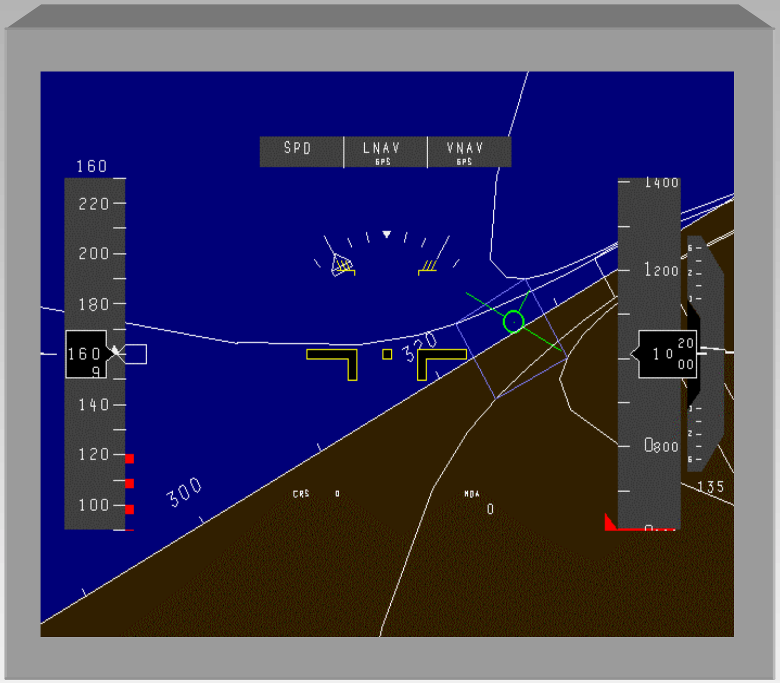
The real-time processor transforms the Velocity Data into the ***Velocity Vector***, $\boldsymbol{V_g = (V_{gN}, V_{gE}, V_{gD})}$. This is used to calculate the ***Flight Path Angle*** and the ***Pseudo-Roll***, which are sent to the display processor along with the position information.

# DELPHINS Display Processor

**Display Processor**

- “Tunnel-In-The-Sky” Display Technology.
- Pioneered by Erik Theunissen at the Delft University of Technology, The Netherlands.
- Three-Dimensional representation of the outside world.

# eHUD Display




Display Image

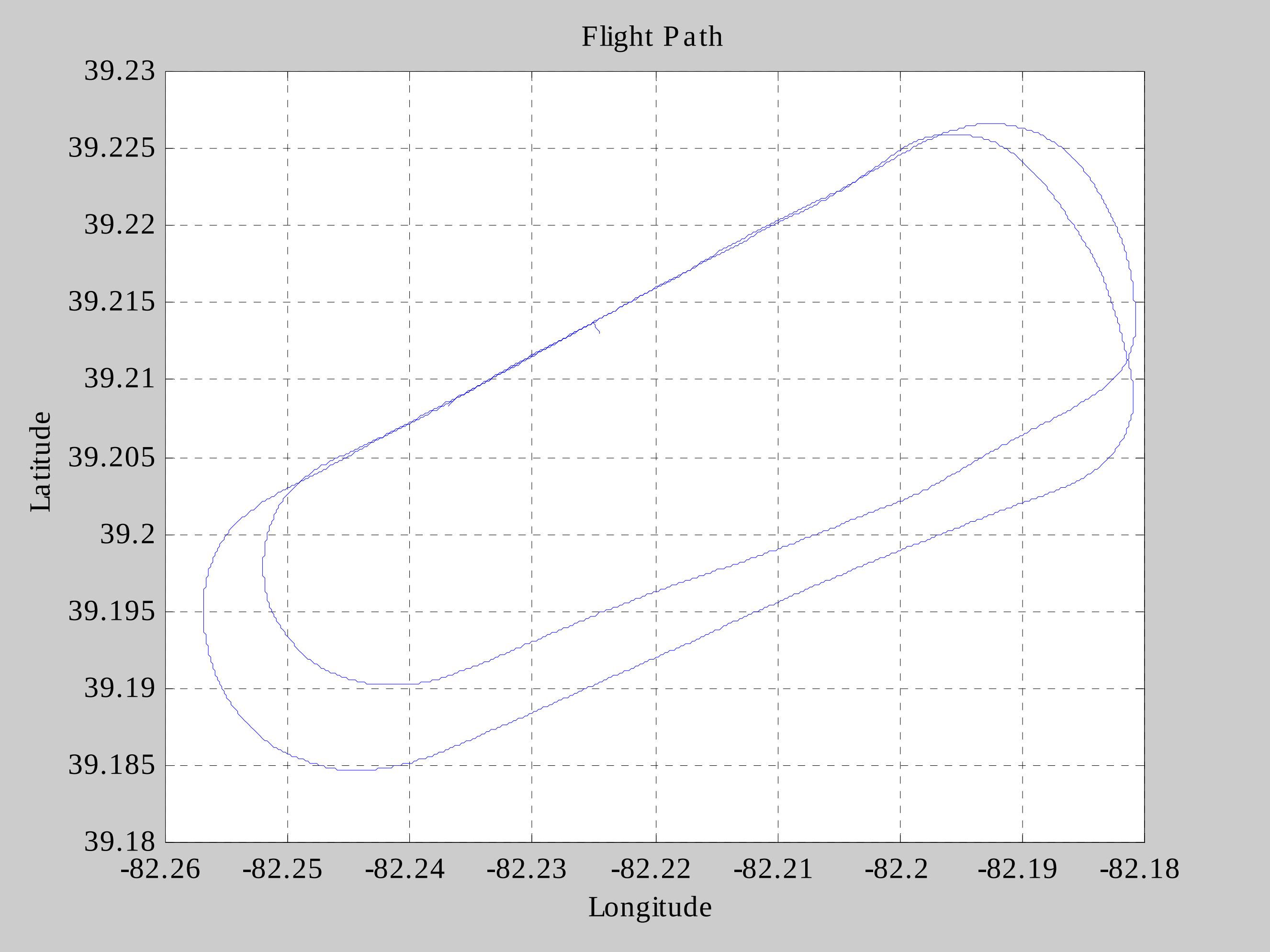
Flat Screen CRT

# Flight Test

**Scenario:**

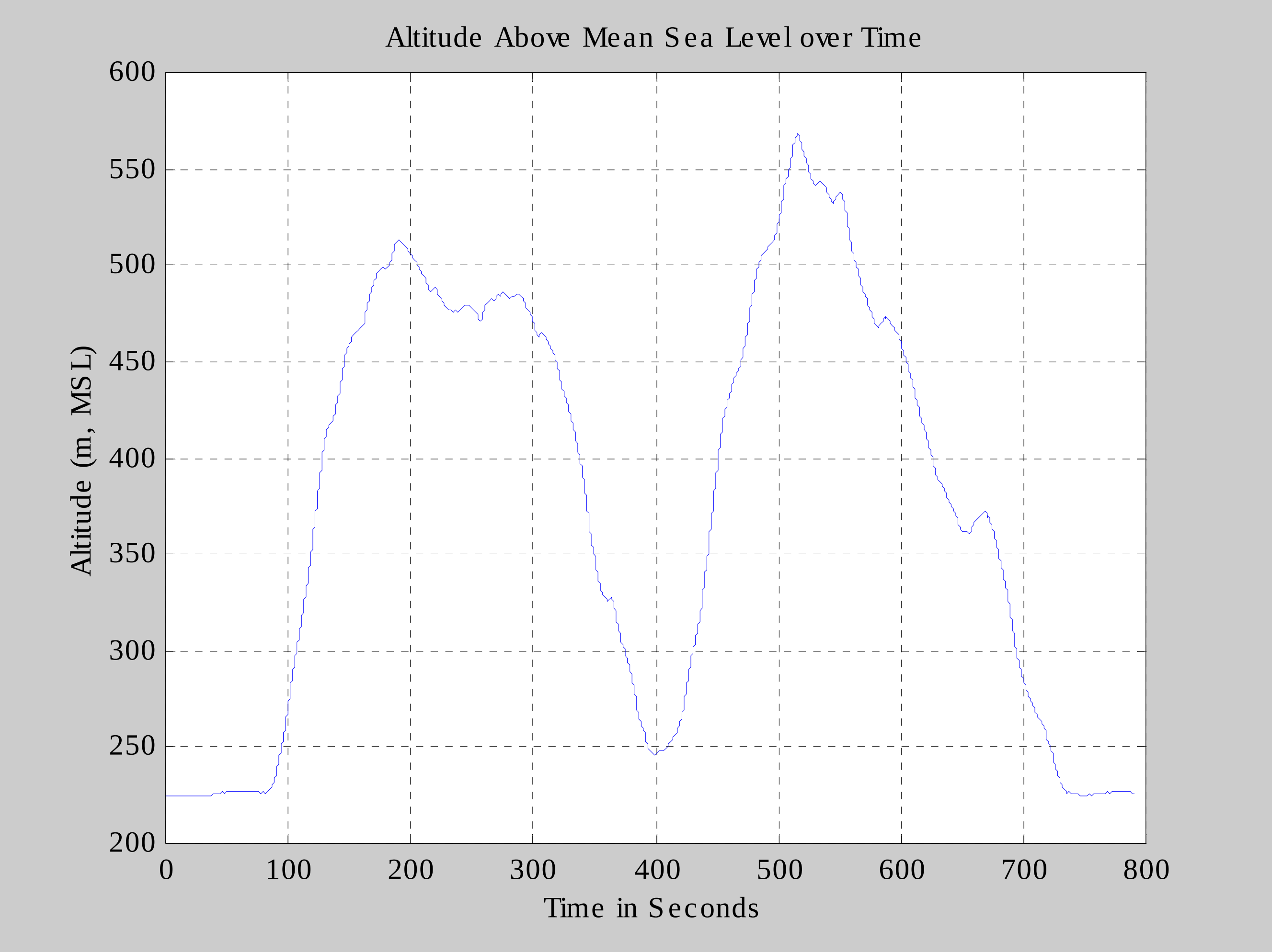
- Last Flight Test was June 8, 2001.
- Wind conditions were a concern.
- Consisted of two approaches on UNI runway 25.
- GPS Antenna mounted approximately above aircraft center of gravity.

# Flight Path



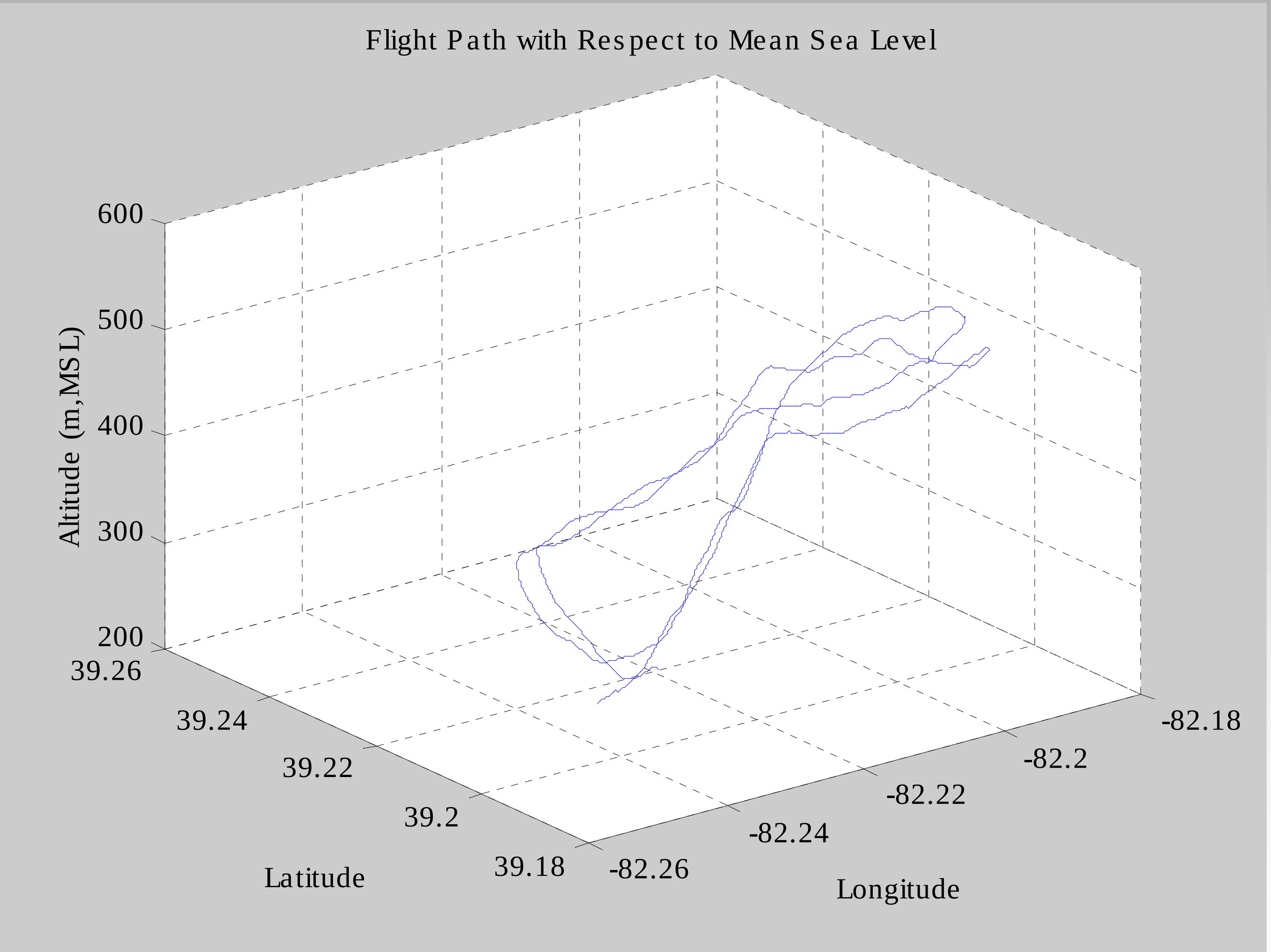
Flight Path
39.23
39.225
39.22
39.215
39.21
39.205
39.2
39.195
39.19
39.185
39.18
Latitude
-82.26
-82.25
-82.24
-82.23
-82.22
-82.21
-82.2
-82.19
-82.18
Longitude

# Altitude Profile



# Flight Path

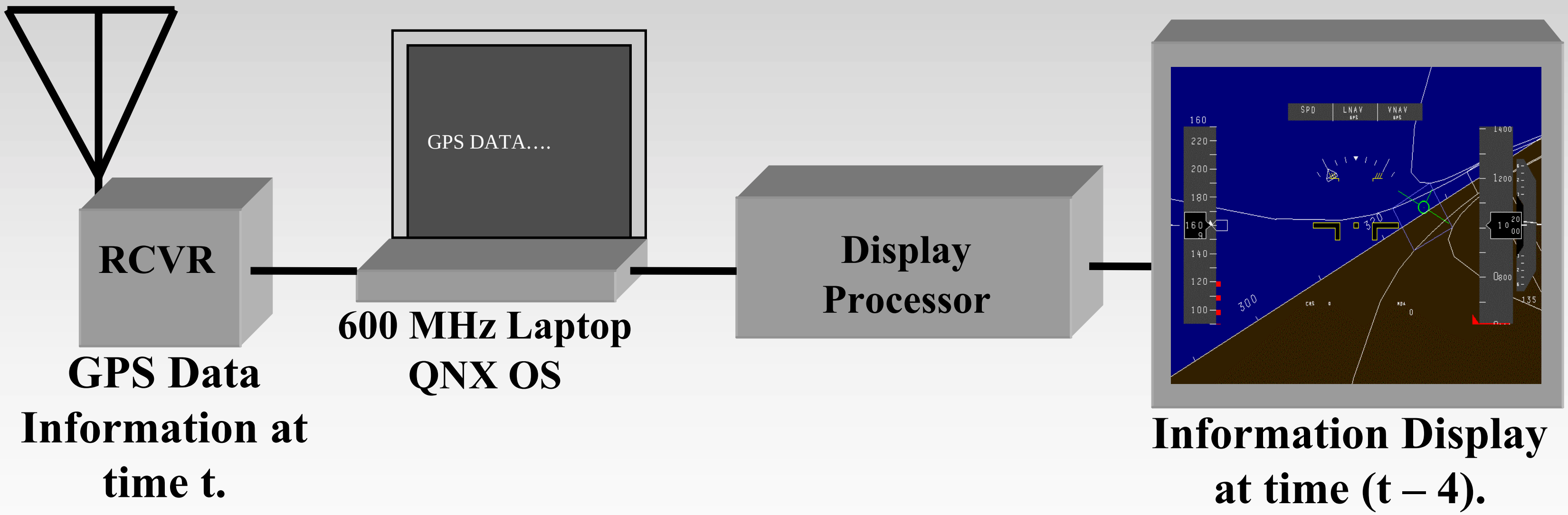
*(Latitude, Longitude and Altitude with Respect to Mean Sea Level.)*



# Flight Test Results

**Results:**

- Four-second delays noted in display image.
- Display seemed to indicate the correct aircraft attitude.
- Flyable once delay problem is sorted out.



# Project Transition

- Have a system that demonstrates initial proof of concept.
- Have solid test data.
- Have a four-second delay problem.
- Conduct Performance Requirement Analysis.

**<u>Check List:</u>**

✓ Novatel Receiver.

*Real time Processing of Velocity Vector.*

✓ DELPHINS Display Processor and Imaging.

# Problem Analysis

- ***Need***: Increase in the number of GA accidents due to flying instrument approaches in IMC conditions.
- ***Goal***: GA display that will help to mitigate problems associated with flying in IMC conditions by enhancing pilot's situational awareness.
- ***Objective***:

  - Must give proper representation of aircraft attitude.

  - Must be easy to interpret (Human Factors).

  - Must be cost effective (Single GPS unit).

  - Must keep pilot looking "out the window" (Human Factors).

  - Must be easy to mount in any GA aircraft.

# Problem Analysis Continued

- ***<u>Constraints</u>***:

  - Less than 500 ms delay for initial proof of concept.

    (Ultimately 100 ms delay or less.)

  - Image must be displayed with zero distortion.
  - Display size will be 22” by 22” for proof of concept.

# eHUD Architectural Overhaul

**Phase 1:**

- Update GPS Receiver to a Novatel OEM4 with 20 Hz position and velocity data (completed).
- Gather flight data with new receiver.

**Phase 2:**

- Re-write Velocity Vector Attitude Determination code to insure timing issues are understood while processing the velocity vector.

**Phase 3:**

- Find an alternative means to display attitude and position information to the pilot.

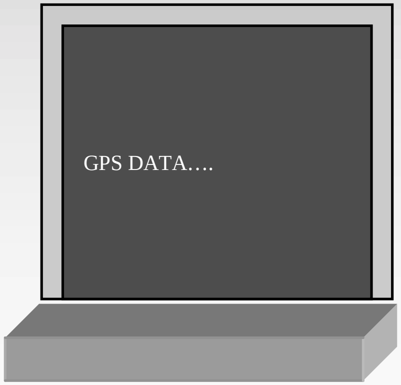
# Phase One

- Gather test data with new Novatel OEM4 20 Hz GPS Receiver.
- Verify flight data to insure a sufficient amount has been gathered before the winter arrives.
- Have two or three unique flight profiles to test against Real-Time Processor and what ever display option is used.

**Novatel 20 Hz OEM4 Receiver**

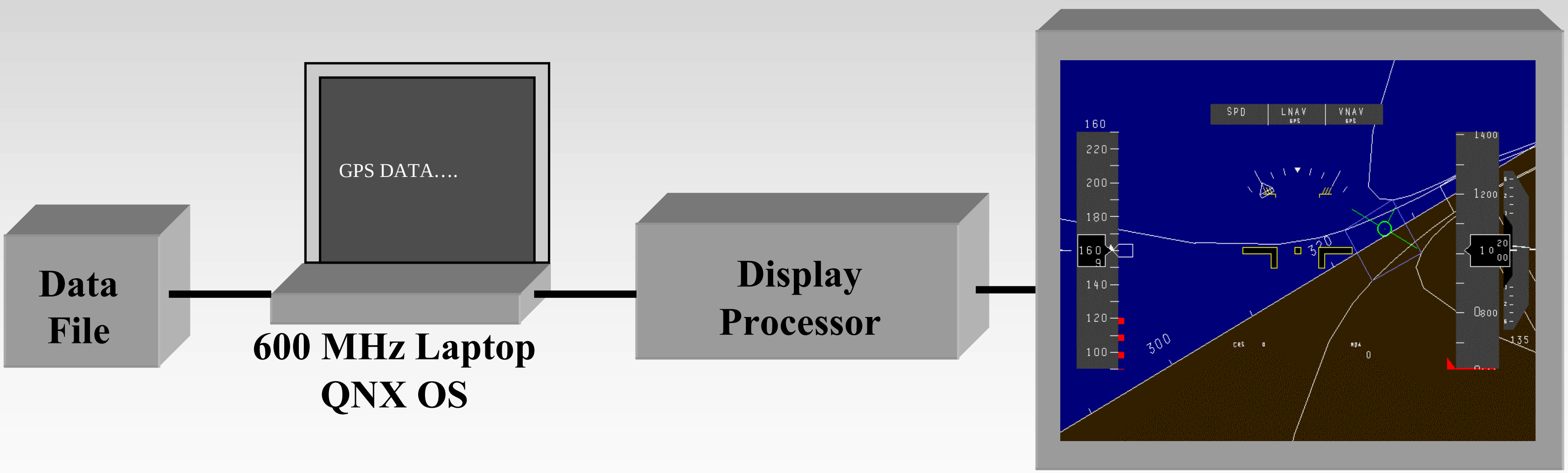
# Phase Two

- Complete re-write of Velocity Vector Based Attitude Determination Algorithm.
- Sample new GPS data file at 20Hz to emulate real-time input from receiver against display option.



# Phase Three

- Bench test entire system with data file to insure that the correct display is being produced for a given flight profile.



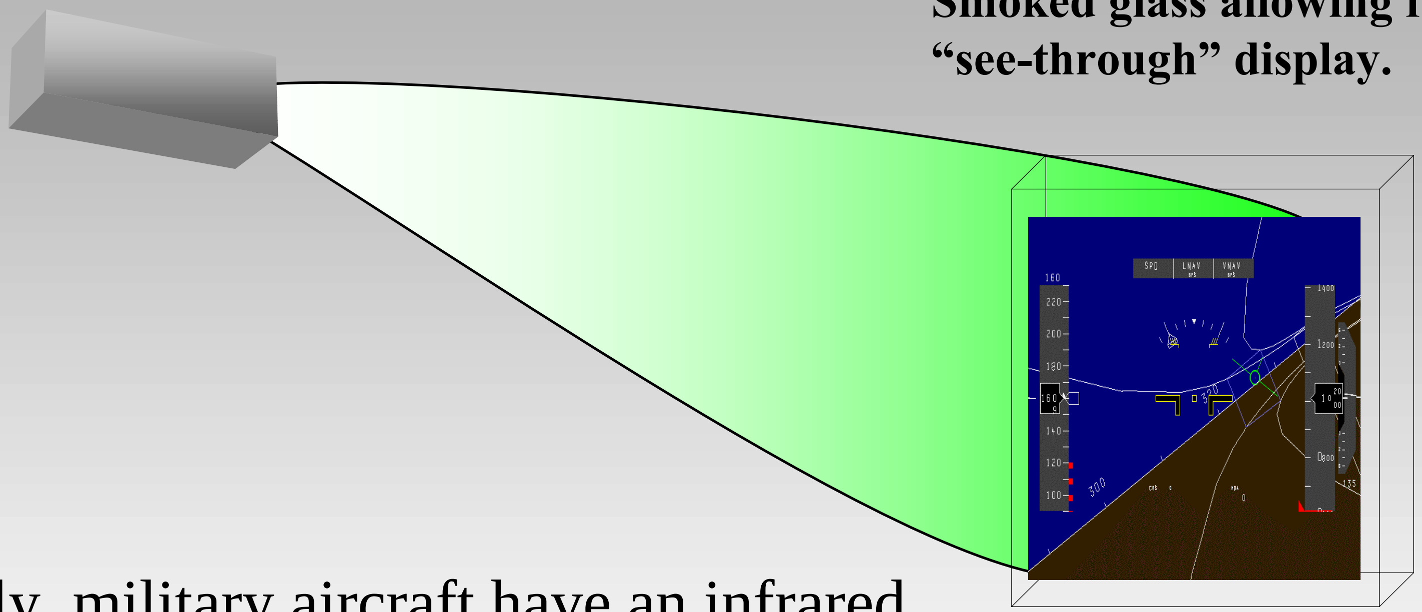
# Future Plans

- Implement phases one, two and three.
- Keep the development of the eHUD completely in-house. Use tools that will allow us to personally develop graphical displays, projection, etc. and not depend on others to make modifications.
- Update the Pilot Display to a modern implementation of Head-Up Displays.

# Modernization of Display

**Projector mounted to ceiling in cabin.**

**Smoked glass allowing for "see-through" display.**




Typically, military aircraft have an infrared camera display in the cockpit providing flight information to the pilot. General Aviation HUD should follow this display convention.

# Contact Information

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# References


- Kornfeld, R.P., Hansman, R.J., Deyst, J.J., *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture.* MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
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